Exhibit A

I. Description of the Heart Model: Generalities

There are many physiologic aspects of the heart to consider when attempting to create an extensible, generalized model of the heart for use in simulating medical procedures. First and foremost of these is completeness. The model should be as complete as possible, modelling all aspects of heart motion and function. To accurately simulate procedures such as cardiac catheterization (left and right), pacemaker placement, and flow dynamics inside the heart, we need to examine two main components of the heart: deformation and electrical characteristics. The second, and counterbalancing, aspect to consider is efficiency. The algorithms used in developing the model should be as efficient as possible, and permit the maintenance of an absolute minimum frame rate of 15-20 frames per second during the simulation.

II. Description of the Heart Model: Electrical Model

The heart is inherently an electrical structure. Its cells are conductors, with properties of resistance and capacitance. Electrical stimuli are received by cells, spread across cell' membranes, and are transmitted to a given cell's neighbors. This system is ideally described through cellular automata, a concept that is uniquely able to describe many biological and non-biological systems for which solutions are otherwise difficult to achieve.

We have developed an efficient and robust representation of the electrical system of the heart using such cellular automata. We have subdivided the heart into a small number of tissue types, each of which has its own conductive properties. Atrial and ventricular cells comprise the bulk fo the heart tissue, and have a slow transmission from cell to cell. Fiber cells are the "wires" of the heart, intended to model Purkinje fibers in both the atria and ventricles. Conduction along these paths is very rapid, and these paths connect many cells. Nodal cells are specialized fiber cells. In addition, each cell - as in the real heart - has an inherent pacemaker rate. The rate for each group of cells depends on the cell being considered. The SA and AV nodes have rates of 70 and 50, aproximately; the atrial tissue has an inherent rate of 300+ but is suppressed under most circumstances. The fiber cells of the ventricle have an inherent rate of 40-50, while the ventricular cells have an inherent rate of 20.

Our model of the heart tracks the membrane potential of each cell as the cell passes through the cardiac cycle. By "probing" areas of the heart - either with a localized probe, as in pacemaker leads placement, or with a global "probe" such as an EKG lead - we can derive an accurate representation of an EKG that is based on the inherent polarization state of the heart. This EKG tracing can then be displayed interactively.

Inherent in this model of normal cardiac electrical behavior is the ability to monitor abnormal electrical states. Our model directly supports modelling the following pathological electrical states:

* atrial fibrillation
* atrial flutter
* ventricular PVCs
* first degree AV nodal block
* second degree AV nodal block (both Wenkebach and Mobitz type II)
* third degree AV nodal block
* ventricular ischemia and ventricular infarction
* reentrant arrhythmias as a result of infarction
* small modifications to the electrical model will easily support modelling
* Wolff-Parkinson-White syndrome
* right and left bundle branch block

In addition to the above, the electrical model directly supports such corrective measures as pacing the heart from either the atria, ventricles, or both. Defibrillation of the electrical model is also supported as a means of escape. This electrical model also runs quite efficiently in real-time: a realistic model of the above can be achieve using only 1200 cells and provides essentially no drain on the CPU. This model can be extended to include more cells (the model can operate stably up to around 50,000 cells).

III. Description of the Electrical Model: Polygonal Model
Having an accurate electrical model is nice - having a beating heart that you can observe is better. We have extensive experience creating deformable models of high polygon counts that run efficiently in real-time. We have adapted many of our routines specifically to allow creation of deformable models of the heart. Our current models consist of casts of the interior of the right heart, for use in pacemaker leads placement. We have tied the deformations of the heart to the electrical model of the heart in such a way that the electrical state of the heart ideally predicts the mechanical state and position of the heat's surface. This binding of the two systems is independent of heart rate: the rate of the electrical model is accurately depicted by deformations, such that our heart model can be seen to beat and beat effectively up to rates of 200 beats per minute.

Inherent in the world of large-scale polygonal models are two facts of life: rendering and collision detection. Rendering (drawing our model in real-time and with interactive frame rates) of large polygonal models is the holy grail of computer graphics. Our technology is capable of handling "crude" heart models of 900+ polygons, maintaining frame rates of 70-80 frames per second (bear in mind that most computer games produce interactive frame rates of 20-40 rendering a small fraction of this number of polygons). Collision detection, crucial for interaction with such models, is another chief drain on the processor for simulation software. For the heart model in particular, deformations can be dramatic; tracking these deformations to provide accurate collision

detection presents a new realm of challenges. We have developed an automatically generated data structure capable of efficiently handling this task. While there is likely still room for optimization in this structure, we can currently handle colision of 100 line segments against our model in under 13 milliseconds. In general, this should be more than enough line segments to create effective models of wire navigation of both the right and left hearts.